General Physics

EXPERIMENTAL INVESTIGATION OF CHAOS IN A ROTATING WATERWHEEL

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The Lorenz waterwheel is a well-known example of a simple mechanical system that exhibits chaotic behavior and can be described by the same set of equations discovered in Lorenz's pioneering study of chaos in atmospheric convection. It is surprising, however, that no experimental study of this mechanical analog of the Lorenz equations has ever been published, especially given the rich structure of the dynamics. In a previous talk, we described theoretical and numerical investigations of the waterwheel, leading to estimates of parameter ranges that seem suitable to the design of a working waterwheel. We now describe the experimental design in more detail and discuss a number of possible experiments.

The wheel itself consists of a thin frame of vacuum-formed polycarbonate to which 36 cylindrical cells are attached, long axes perpendicular to the plane of the wheel, at about a 23 cm radius. The wheel is attached to a platform via bearings, and the platform can be tilted to an angle up to 45˚ above the horizontal. Water is introduced through a metering flow valve into a manifold that allows the angular distribution of the input flow at the top of the wheel to be varied. The angular position of the wheel is measured with a shaft encoder interfaced to a multi-purpose data acquisition board in a desktop Macintosh computer. Numerical differentiation of the angular position time series data gives $\omega(t)$, and the other two Lorenz variables are not directly measured. Portraits of the strange attractor can be produced via time delay embedding of the $\omega(t)$ data.

One important element in the chaotic waterwheel is the introduction of dissipation in the form of a braking torque, preferably proportional to the angular speed. In the original Malkus design, built at MIT in the early 1970's, this braking was produced by a bushing containing viscous oil. Our design uses an eddy current brake consisting of a thin aluminum ring at the periphery of the wheel that passes between the pole faces of a variable gap magnet. The eddy current drag produces a torque proportional to the angular speed. Measurements were made of the terminal velocity of a test wheel driven by a falling weight for various magnet gap spacings. These measurements were then used to determine the braking constant ν ($\tau = -\nu\omega$) as a function of the gap spacing. These data and other design specifications will be described. Preliminary data used to estimate the contribution from bearing friction will also be discussed. Finally, we discuss a range of future experiments to investigate, e.g., the effect of various angular distributions of the input water flow, possible synchronization of chaotic motion to a small sinusoidal disturbance, and the effect of inertial damping.